cor. proc	Coracoid process of scapula
cost. surf	Costal surface of scapula
cran	Cranium
cran. proc	Cranial process of sternum
delt	Deltoideus muscle
elast	Elastic fibers
ext	Extension
flex	Flexion
glen. cav	Glenoid cavity
glen. hum. lig	Glenohumeral ligament
glen. lig	Glenoid ligament
great. tub	Greater tubercle of humerus
hum	Humerus
hum. head	Head of Humerus
hyo	Hyoid bone
in	Inward rotation
infraspin	Infraspinatus muscle
infraspin. fos	Infraspinatous fossa of scapula
interos. membr	Interosseus membrane
later. proc	Lateral process of sternum
ster. acr. lig	Sternoacromial ligament
ster. cav	Joint cavity of sternum
ster. glen. lig	Sternoglenoidal ligament
ster. hum. lig	Sternohumeral ligament
ster. hum. mast	Sterno-humero-mastoideus complex
ster. hyo	Sternohyoideus muscle
ster. mast	Sternomastoideus muscle
sterneb. 1,2,3	Sternebrae 1,2,3 of sternum
ster. thyr	Sternothyroideus muscle
subdelt. bur	Subdeltoid bursa
subscap	Subscapularis muscle
subscap. bur	Subscapular bursa
supraspin	Supraspinatus muscle
supraspin. fos	Supraspinatous fossa
synov. cav.	Synovial cavity
ter. maj	Teres major muscle
ter. min	Teres minor muscle
thor	Thorax
thyr	Thyroid cartilage
thyr. hyo	Thyrohyoideus muscle
trap	Trapezius muscle
ventr. proc	Ventral process of sternum

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Age structure and sex ratio of the ringed seal Phoca (Pusa) hispida Schreber population in the Bothnian Bay, northern Baltic Sea

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Abstract

Studied the age structure and sex ratio of the ringed seal [*Phoca (Pusa) hispida* Schreber] population in the Bothnian Bay, the northernmost part of the Baltic Sea, in 1972–79. The material consisted of 474 specimens captured from seal nets in October-November, and 64 specimens shot on ice in April–May.

The mean age of both the autumn and spring samples exceeded 10 years, the females being on average three years older than the males in the autumn material. The mean age of the catch rised 0.5–0.6 years per year during the study period in the autumn material. Life-table is presented separately for males and females. The average annual mortality rate over five-year periods differed only at the age of 11–15 years, when the mortality in the males exceeded that of the females. The mean life expectancy was high, for females 5.7 and for males 4.8 years at the age of 20 years, for instance. The oldest specimens were a 40-year-old male and a 37-year-old female. The proportion of males was 46.2%, although the sex ratio was dependent on age, the proportion being 56.3% males at 0–10 years, 54.3% at 11–20 years, and 31.8% over 20 years. The foetal sex ratio was 1:1. The ageing of the population promises a menaced future for the Baltic ringed seal, when the specimens born at the time of normal reproductivity (before the late 1960's) begin to be lost in a noticeable degree through natural mortality.

Introduction

The Baltic seal populations have been subject to remarkable changes during a good decade. First, the hunting pressure has weakened sharply since 1967 (Helle 1979b). The annual catch in the northern Baltic was still 5400 on average in the mid-1960's (see Söderberg 1975; Tormosov and Rezvov 1978; Bounty statistics from the Ministry of Agriculture and Forestry, Finland), and even the onset of sexual maturity had fallen because of excessive hunting pressure (Söderberg 1978). Secondly, the ringed seal population has suffered from serious reproductory disturbances since the late 1960's (Helle 1975, 1978). Although sealing has been carried on commonly in earlier days, the basic information required for rational exploitation, i. e. age stucture, sex ratio, reproductive capacity, has scarcely been available for the Baltic Sea area.

The purpose of the present paper is to study the age structure and sex ratio of the ringed seal [*Phoca (Pusa) hispida* Schreber] (on the systematics see Burns and Fay 1970) in the Bothnian Bay, the northernmost part of the Gulf of Bothnia, in order to get a starting point in following the effects of above mentioned changes.

Material and methods

The majority of the material comprises ringed seals captured from seal nets at Simo on the Bothnian Bay (65°35'N, 25°E) in October and November 1972–78. The seal nets were located at distances of 1.5–5 km from the coast in water of depth 5–10 metres. The mesh size of the nets was 60 or 80 cm when measured around. The seals drowned soon after becoming entangled in the nets, which were anchored tightly to the bottom. Details of trapping procedures have been described earlier (Helle 1979a).

Z. Säugetierkunde 45 (1980) 310–317

ISSN 0044–3468/ASTM-Coden ZSAEA 7

Ages were determined from a further 64 ringed seals shot on the ice of the northern Bothnian Bay in April–May in 1973–79.

The material in different years is presented in table 2.

Age determination was based on the layered structure of the canine teeth (Scheffer 1950; Laws 1952). It was generally determined from several points on the cementum, and only occasionally from the dentine. Ages are indicated here in full years, although in practice the seals caught in the spring were 1–3 months older than this and those caught in the autumn 6–8 months older.

Since the mating season of the ringed seal in the Bothnian Bay occurs in February–March (Olofsson 1933; Granlund 1975), the foetuses encountered were at 7–9 months of development by the trapping season and could thus easily be sexed.

One might imagine that, as in other net techniques, the mesh size of the seal net would lead to a pronounced under-representation of young specimens in the catch (see fig. 2), but this is not the case, as the average maximum girth of the ringed seal during its first autumn is already about 90 cm (Helle 1979a), well in excess of the mesh size. Some of the young animals may, of course, have escaped from the net by wriggling through it or turning back. Such disentanglings give rise to an obvious disarrangement of the net, and since relatively few cases of this were discovered, it may be concluded that the young age classes are absent for reasons other than the selectivity of the mesh size.

It seems possible that the under-representation of young age classes in the catch may be a consequence of the behaviour pattern of the ringed seal in late autumn. Trapping takes place just as the coastal waters are freezing, and the ringed seals leave the trapping waters for the outer sea, forced on by the ice margin, which is moving progressively further away from the shore. Under these circumstances the specimens caught tend to be those which will overwinter on the ice of the Bothnian Bay. The author is also of the opinion that these are sexually mature individuals, which will spend the mating season in this area in February–March. Thus the younger, immature seals may be absent, having migrated at an earlier stage to winter in easier ice conditions closer to the ice margin in more southern areas (see Granlund 1975).

Results

Age structure

Autumn sample

The age of the ringed seals captured was high, the mean exceeding ten years in every year (fig. 1), and the females being on average three years older than the males. The regression line for the mean age of the catch (fig. 1) shows this to have risen by 0.5 years per year in the males and 0.6 years per year in the females in 1972–78.

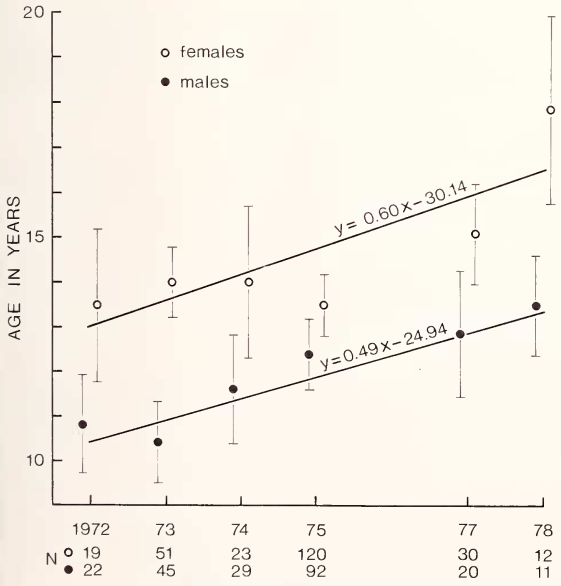

Fig. 1. Mean age (± S. E.) of ringed seals captured with seal nets in the Bothnian Bay in October-November in 1972–1978 (for females r = 0.821, $p < 0.05$, and for males r = 0.952, $p < 0.01$)

The distribution of the specimens into year classes is often uneven in samples like the present ones, and this has therefore been smoothed for further handling (fig. 2). The cubic regression equations are calculated for specimens born in 1966 or earlier. This was chosen as the limit of acceptance since 1. the first signs of reproductive failures, so common nowadays, were observed in 1967 (Helle 1979b), and 2. hunting pressure decreased sharply after 1967 (Bounty statistics from the Ministry of Agriculture and Forestry, Finland), leading to the present declining phase in the ringed seal population.

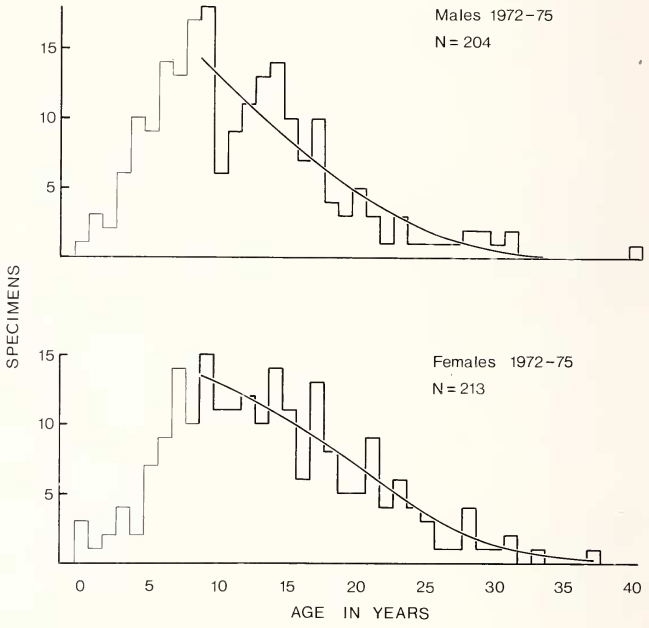

Fig. 2. Percentage distribution of ringed seals captured with seal nets by year classes in the Bothnian Bay in October-November, 1972–75. The regression for males older than eight years is of the form $y = 0.00015x^3 + 0.01233x^2 - 1.31042x + 24.66525$, and that for females of the same age $y = 0.00129x^3 - 0.07496x^2 + 0.73567x + 11.80408$.

Certain essential parameters in a population may be studied by means of a life-table. Because of the marked under-representation of young specimens in the present material, no adequate life-table can be composed directly from the age distribution in the catch. One may be built up, however, on the base of 1. the age structure of the seal stock of reproductive age and 2. the reproductive capacity. The present life-table (table 1) is composed using the age structure of the present study and the computed natural reproductive capacity of the species in the eastern Canadian arctic (see Smith 1973).

Mortality during the first 10 years of life is about 84% in both the males and females in the present material. After that the annual mortality rate of the males exceeds that of the females in the 11–15 year age group, and the averages for the subsequent five-year periods progress in the following way:

The oldest ringed seal obtained was a 40-year-old male, and the oldest female was 37 years of age. 8.9% of the males and 17.8% of the females were over 20 years of age. The mean life expectancy was high: 10.9 years for females and 8.3 for males at 10 years of age, 5.7 and 4.8 years respectively at 20 years and 2.7 and 1.3 years at 30 years (table 1).

Erratum

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By a mistake in the paper "Age structure and sex ratio of the ringed seal *Phoca (Pusa) hispida* Schreber population in the Bothnian Bay, northern Baltic Sea" by E. HELLE, the following table:

Age in years	Males	Females	t-test	p
11–15	8.8	5.0	2.79	<0.01
16–20	11.8	8.7	1.55	>0.10
21–25	16.4	13.6	0.88	>0.10
26–30	23.0	21.7	0.22	>0.50

has been printed together with table 2 on p. 314. Correctly it should be placed on p. 312 before the last paragraph.

Spring sample

The age distribution of the spring catch is depicted in Fig. 3. The catch is composed of quite old specimens, with mean age over 10 years in every year except 1975. A marked increase in age seems to have taken place between 1975 and 1978, as the mean age in 1973–75 was 9.8 years, whereas that for 1978–79 had risen to 13.9 years ($t = 2.18$, $p < 0.05$).

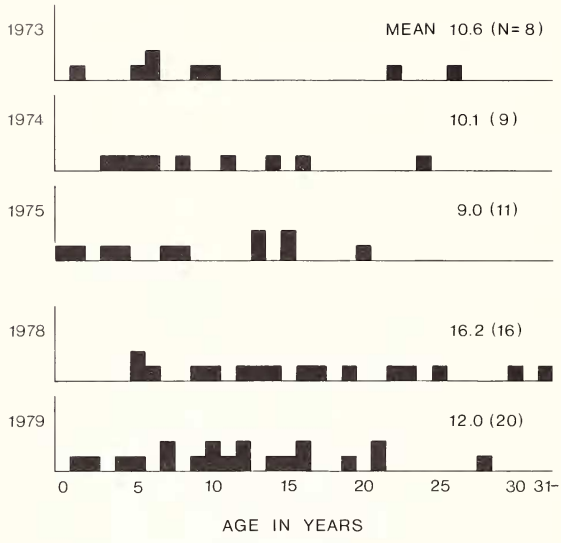

Fig. 3. Age distribution of ringed seals shot on the ice of the Bothnian Bay in April-May in 1973–1979.

Sex ratio

The sex ratio in the net catch from Simo was 1:1 in the individual years (table 2). In the total material from 1972–78 the proportion of males, 46.2%, was nevertheless indicative of certain trend, and a more detail approach of the most representative annual catch (1975) reveals the sex ratio to be age-dependent. In periods of five years up to 20 years of age the sex ratio

Table 2

Sex ratio of the ringed seal population in the Bothnian Bay in 1972–79

Sample		Sample size	Males (%)	Chi square	p
Autumn	1972	41	53.7	0.10	>0.50
	1973	96	46.9	0.26	>0.50
	1974	52	55.8	0.48	>0.30
	1975	212	43.4	3.70	<0.10
	1977	50	40.0	1.62	>0.20
	1978	23	47.8	0.04	>0.80
Total		474	46.2	2.74	<0.10
Spring	1973–79	64	50.0		
Foetuses Autumn	1973–78	56	51.8	0.02	>0.70

Age in years	Males	Females	t-test	p
11–15	8.8	5.0	2.79	<0.01
16–20	11.8	8.7	1.55	>0.10
21–25	16.4	13.6	0.88	>0.10
26–30	23.0	21.7	0.22	>0.50

remained statistically 1:1, but later on it was significantly predominated by females (χ^2 = 4.64, $p < 0.05$). The sex ratio of the spring catch was even (n = 64), as was the case also within the foetuses in autumns 1973–78 (51.8% males, n = 56 in total).

Discussion

Mortality rates of pinnipeds vary greatly, depending on the species concerned and the hunting pressure, for instance. Thus the polygamous grey seal (*Halichoerus grypus*) has an annual mortality rate of 40% in territorial males (over 10 years of age), but only 6.7% in females (Hewer 1964), and the pattern is similar in the American stock of the species (Mansfield and Beck 1977). A higher mortality in males is also found e. g. in the harbour seal (*Phoca vitulina*), with 29% for males of 5 years and older, compared with about 15% for females (Bigg 1969), and in the hooded seal (*Cystophora cristata*) in some areas (Øritsland and Benjaminsen 1975). Annual mortality rates falling below 10% are encountered in the walrus (*Odobenus rosmarus*) (Fedoseev and Goltzev 1969), and the antarctic crabeater seal (*Lobodon carcinophagus*) and leopard seal (*Hydrurga leptonyx*) (Øritsland 1970).

Mortality rates for the ringed seal are 15–17% in exploited populations in Canada (Smith 1973) and about 20% in the Sea of Okhotsk (Fedoseev 1968), figures which are in excess of present results for the Bothnian Bay ringed seal. The present figures of a good 10% would agree with the mortality in slightly exploited or almost totally virgin populations, for the natural mortality in the Sea of Okhotsk is 11% (Fedoseev 1968), and has been calculated as 10% in an unexploited population in Canada (Smith 1973).

The present mortality figures may nevertheless be slightly biased for ages of up to about 15 years because of the severe hunting pressure in the mid-1960's (see Helle 1979b), which has led to low numbers of specimens of about 10 years of age in the present age distribution. The steep decrease in the hunting catch since 1967 (Helle 1979b), on the other hand, is reflected in the higher survival rates among the older age classes. This and the lower reproductive capacity have caused the mean age of the catch to increase (figs. 1, 3; see Nazarenko and Timoshenko 1974, Kapel 1975).

The present life-table (table 1) offers a starting point for following trends in the age structure of the ringed seal population in the Bothnian Bay. The main factor affecting this nowadays and likely to do so in the near future is the exceptionally low reproductivity of the females (Helle 1978), whereas the catch from hunting and entanglement in fishing gear had diminished to about one hundred a year by 1975 (Bounty statistics from the Ministry of Agriculture and Forestry, Finland), and continues to decrease.

Members of the genus or subgenus *Pusa* (Burns and Fay 1970) seem to be among the most longaevous species among the Pinnipedia. The oldest of all are the Baikal seal (*P. sibirica*), max. 56 years, and the Caspian seal (*P. caspica*), max. 50 years (Eibatov 1976). The oldest ringed seal, 43 years, has been reported from Canada (McLaren 1958) and the maximum known lifespan of the Baltic ringed seal appears from the present relatively small material to be 40 years. It is worth noting that all these, excluding the Canadian ringed seal, live in fresh or brackish water and lack natural enemies, so that the direct effect of hunting pressure on the life-span might be of great importance.

A predominance of males within the new-born pups is reported in the case of the grey seal (e. g. Boyd and Campbell 1971; Mansfield and Beck 1977) and the hooded seal (Øritsland and Benjaminsen 1975), but the ratio is reversed by the first moult in the former species (Boyd and Campbell 1971) and by the adult stage in the latter (Øritsland and Benjaminsen 1975). The sex ratio of foetuses at about 7 months of age in the present study was 1:1, but it is not known whether the high mortality in the earlier foetal stages (see Helle 1978) is directed equally towards males and females. The postnatal sex ratio of the ringed seals was even up to 20 years of age and became female-dominated thereafter through the